

GROWTH EXPERIMENT OF NARROW BAND-GAP SEMICONDUCTOR
PbSnTe SINGLE CRYSTALS IN SPACE
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Tomoaki Yamada
NTT Basic Research Laboratories
Japan

Abstract

An experiment on crystal growth of $Pb_{1-x}Sn_xTe$ in microgravity is planned. This material is an alloy of the compound semiconductors PbTe and SnTe. It is a promising material for infrared diode lasers and detectors in the wavelength region between 6 and 30 μm . Since the electrical properties of $Pb_{1-x}Sn_xTe$ depend greatly on the Pb/Sn ratio and crystalline defects as well as impurity concentration, homogeneous, defect-free, high-quality crystals are anticipated. Although many growth methods, such as the pulling method, the Bridgman method, the vapor growth method, etc., have been applied to the growth of $Pb_{1-x}Sn_xTe$, large, homogeneous, low-defect-density crystals have not yet been grown on Earth. The unsuccessful results have been caused by buoyancy-driven convection in the fluids induced by the specific gravity difference between heated and cooled fluids on Earth.

Figure 1 shows a schematic view of $Pb_{1-x}Sn_xTe$ crystal growth in this experiment. A crystal is grown by cooling the melt from one end of the ampoule.

In crystal growth from the melt, about 30% of the SnTe in the melt is rejected at the solid-liquid interface during solidification. On Earth, the rejected SnTe is completely mixed with the remaining melt by convection in the melt. Therefore, SnTe concentration in the melt, and accordingly in the crystal, increases as the crystal grows, as shown in Figure 2.

In the microgravity environment, buoyancy-driven convection is suppressed because the specific gravity difference is negligible. In that case, the rejected SnTe remains at the solid-liquid interface and its concentration increases only at the interface. If the growth rate is higher than the PbTe-SnTe interdiffusion rate, the amount of SnTe which diffuses from the interface into the melt increases as SnTe piles up at the interface, and finally it balances the amount of rejected SnTe during solidification, resulting in steady-state SnTe transportation at the interface. By using this principle, compositionally homogeneous crystals can be grown (Figure 2). Furthermore, low-defect-density crystals will be grown in microgravity, because convection causes crystalline defects by mixing hot and cold fluids and generating temperature fluctuations in them.

Expected Results

Currently, the development of electronic technology is very rapid. This is due to the development of fabrication techniques for semiconductor materials and devices, called "Si-technology." Great improvements in device performance and large-scale integration of devices have been made based on crystal growth techniques for growing large, high-quality crystals. The quality of $Pb_{1-x}Sn_xTe$ is presently much poorer than that of Si.

$Pb_{1-x}Sn_xTe$ is a promising material for infrared detectors and diode lasers. Growth of large, homogeneous and low-defect-density crystals will enable mass production of high performance devices at a cheaper cost and the development of integrated Si-like circuits. As a result, infrared detectors will be put into practical use as heat sensors in a variety of fields. For example, they may be used in heat controllers of furnaces, engines, machines, etc.; in security

instruments for automobiles, houses, factories, etc.; and in medical apparatuses for diagnosing diseased portions of the human body. Moreover, integration of detectors results in large-area image sensors and enables high-speed processing of infrared images. Such image sensors will be used for remote sensing instruments in resource satellites or Earth observation satellites and will greatly improve sensing ability. They will assist in assessing mining, marine, and agricultural products and in observing the Earth. Infrared diode lasers will be used in chemical analysis apparatuses and will serve to measure or monitor the gas concentration of CO_x , NO_x , SO_x , CH_4 , etc. in the air. Results obtained from the experiment will also assist in understanding the crystal growth mechanism and the behavior of fluids in microgravity.

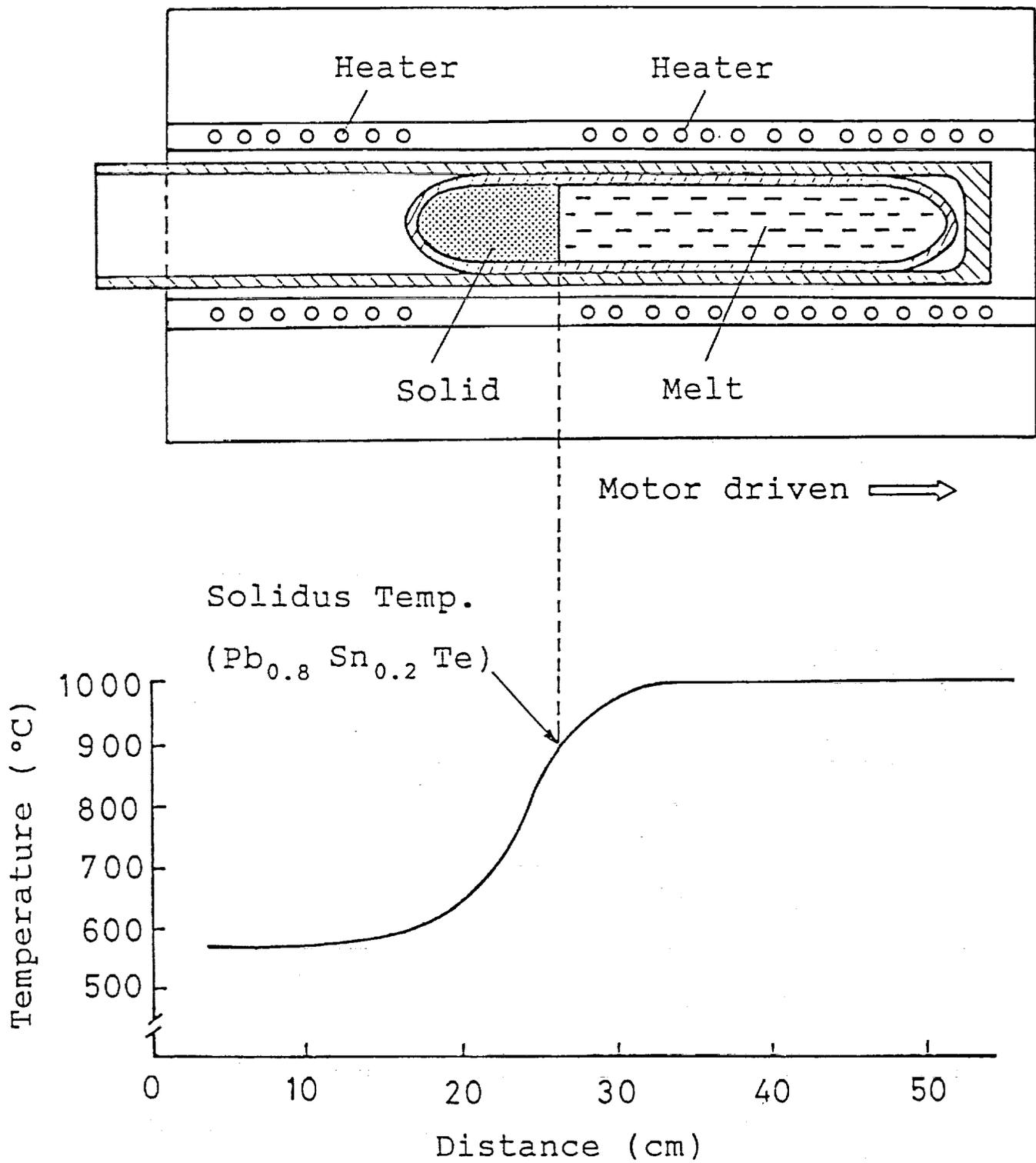


Figure 1. Schematic view of $Pb_{1-x}Sn_xTe$ crystal growth using the Bridgman method.

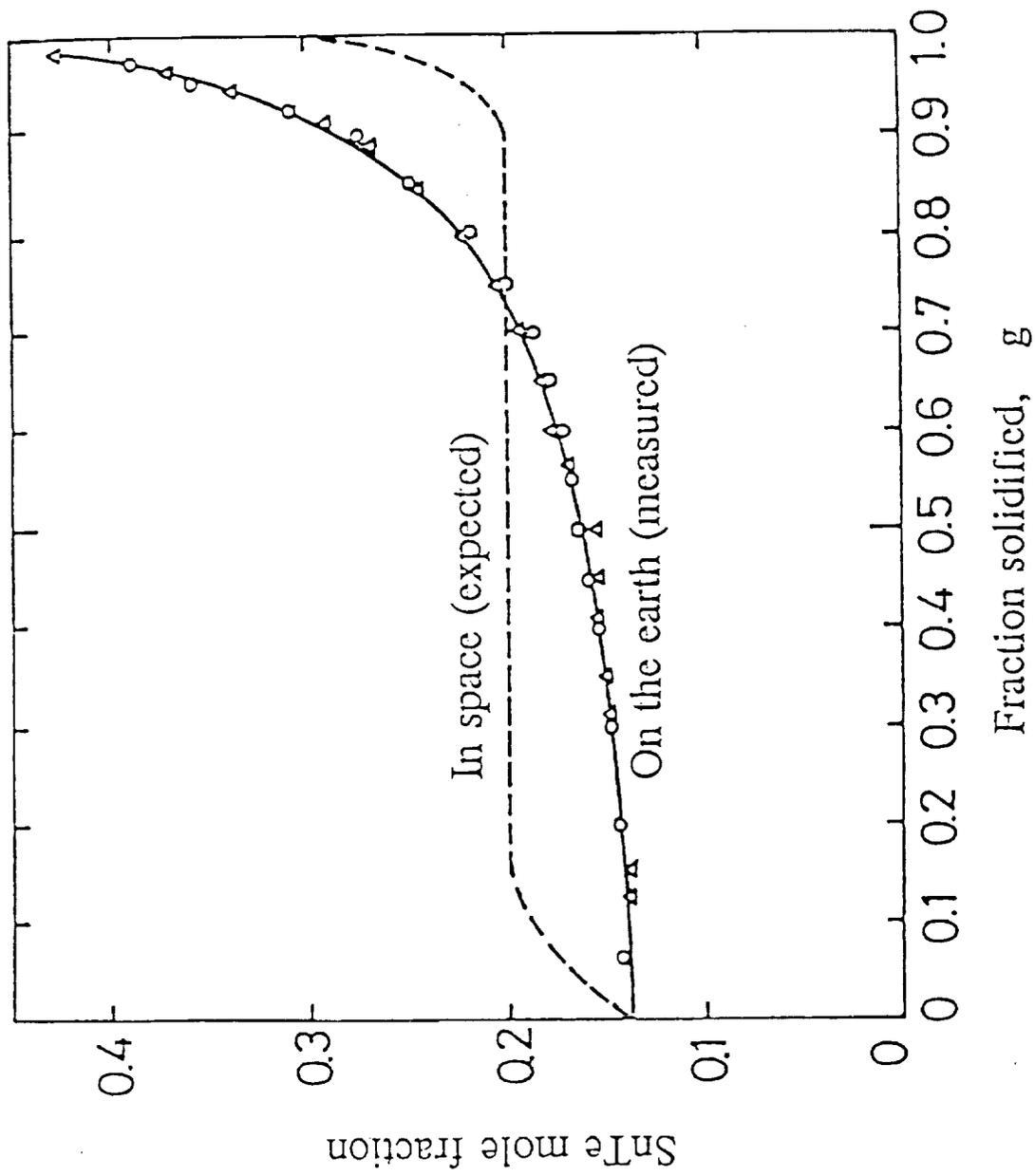


Figure 2. Comparison of compositional profiles between Earth-grown and space-grown crystals.

